Alternative: Efficiently Convey Water to Reduce Loss

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1. Summary of the Alternative

As a major component of a water delivery system, conveyance (or carriage) is the action of moving water from one point to another. Beginning at some water source and ending in some consumptive activity, large and small quantities of water are conveyed for irrigation, livestock watering, domestic, and/or commercial/industrial uses. Water conveyance requires energy and physical structures. Typically, water is conveyed in some sort of open or closed conduit, such as a channel, tunnel, canal and/or pipe, and is moved by some driver, typically gravity and/or an energized pump.

For a variety of reasons, conveyance facilities and systems, when in use, are often a source of water loss. Pipes and canals leak. Water escapes from channels through evapotranspiration processes. To the extent desired or required, leakage and evapotranspiration can be minimized in manmade or modified natural conveyance structures and systems through appropriate facility planning, design, construction, and operation/maintenance activities.

Some conveyance facilities leak more than others do. The amount of conveyance system and/or facility leakage is commonly interpreted as an appraisal of its efficiency: the less a conveyance system leaks or loses water, the more efficient it is.

This white paper briefly examines the following four alternative conveyance systems or possible modifications to conveyance systems to determine if they might represent an increase in conveyance efficiency and, therefore, a potential water savings (from the reduction of perceived water losses):

- Construction of lined canal and/or installation of pipe irrigation delivery systems

- Transport or delivery of water from the San Juan-Chama Project through a regional pipeline

- Repair and maintenance of public water supply systems to reduce levels of unaccounted-for water that are above and beyond acceptable industry standards

- Use of regionally managed and operated systems to optimize water distribution/ management

These alternatives focus primarily on methods to use existing resources (water and energy) more wisely and reduce risk during times of drought. It is unlikely that any of these alternatives could result in new water to meet growing demand. The lining of an acequia, for instance, may improve the ability to deliver water to end users on a ditch, which is particularly crucial during periods of low flow. However, the reduced amount of seepage does not necessarily mean that more water is available for new uses, particularly when flows are low. In some situations it may be possible to prove that the lining of a ditch will actually save water that was not otherwise put to beneficial use. For the most part, however, the alternatives discussed in this paper focus on improving the system efficiency rather than providing new supplies for growing demand.

1.1 Linings and Pipes for Unlined Irrigation Channels

Approximately 62,000 acre-feet of water flows from wells and surface diversions for irrigation within the limits of the Jemez y Sangre planning region (DE&S, 2001). This water is conveyed through canals, ditches, and pipes to agricultural fields. In much of the conveyance system, some water is lost through evapotranspiration and infiltration. In 1999, off- and on-farm conveyance losses in canals and laterals in New Mexico were estimated to be about 36 percent of the total surface withdrawals for irrigation (NM SEO, 1992).

The main contributor to these losses was reported as seepage and excessive vegetative growth. Installation of canal lining systems such as impervious soils, soil-cement, concrete, blocks, and piping systems can decrease up to 95 percent of this total loss.

Water that evaporates while it is in the irrigation canal is lost to the atmosphere. Some water that seeps into the ground through unlined canals is used for transpiration by peripheral vegetation and is therefore lost to vegetation. The balance of the water that seeps into the ground through unlined canals to some extent recharges the existing groundwater aquifer. These losses are part of the overall water balance that exists in an irrigation system where diverted or withdrawn water is primarily used for crop transpiration. The two major components of these losses are seepage of water from agricultural fields into the ground and drainage of water off agricultural fields to some surface watercourse.

The main difference between piped delivery systems and lined canals is that evaporation losses that occur in canals are virtually eliminated in a closed conduit system. However, piped irrigation conduits are difficult to keep clean and operating as irrigation water typically carries solids and debris that can choke pipes.

1.2 San Juan-Chama Water Regional Pipeline

The Bureau of Reclamation's San Juan-Chama Project is a transbasin diversion system that imports water from tributaries of the San Juan River into the Rio Grande Basin. The water is delivered through the Azotea Tunnel, which runs under the Continental Divide to Willow Creek and then to the Rio Grande via Heron Reservoir and the Rio Chama. Since initiation of diversions in 1970, the San Juan-Chama Project has imported an average of 94,200 acre-feet of water into the Rio Grande Basin annually. Water users such as the City of Albuquerque, Middle Rio Grande Conservancy District (MRGCD), U.S. Department of Energy, and other municipalities and irrigation districts contract with the Bureau Reclamation for San Juan-Chama Project water (U.S. Army Corps of Engineers, 2001).

In the planning region, 10,835 acre-feet of water are allocated to municipal and irrigation entities. This water now flows from Heron Dam along the Rio Chama and the Rio Grande to and through the planning region, where withdrawals can be made as required. Beginning at Heron, which is close to 53 miles north of the City of Santa Fe, some of this water flowing in the Rio Chama and Rio Grande is lost through open water evaporation and through transpiration by non-crop vegetation along the river channels. Transporting this water from Heron through a closed conduit such as a tunnel or large-diameter pipe would eliminate virtually all of these losses and result in a corresponding increase of delivered water to the planning area equal to the amount lost. This paper briefly examines the piping of only the San Juan-Chama water that is allocated to the planning area.

1.3 Water Distribution System Repair and Maintenance

Water intended for municipal and industrial uses is conveyed from groundwater and surface water points of withdrawal to points of use through transmission and distribution piping systems. These pressurized piping systems typically exhibit some leakage due to a variety of reasons. Chiefly, poor initial planning and design, poor materials, poor construction, poor operations and maintenance (O&M), and finally, age and normal wear and tear can each, alone or in combination, be the cause. In most potable water systems, leakage from pipelines is probably the largest component of what is known as "unaccounted-for water."

The elimination of unaccounted-for water in potable water systems should be an O&M goal in all municipal/industrial water systems. Currently an acceptable level of unaccounted-for water is considered to be around 15 percent of the total water produced in a system (Mays, 2000). Every water system is different, however, and this figure is at best a rule of thumb to be viewed with caution depending on actual system configuration, size, customer types and distribution, and age.

In the planning region, approximately 18,500 acre-feet of groundwater and surface water is withdrawn and diverted into large and small municipal potable water systems (DE&S, 2001). Currently, it is estimated that just over 13 percent of this water is unaccounted for. A leak detection and repair program could reduce this percentage to some agreed upon level beyond the "reportedly acceptable" 15 percent; however, all leakage could never be eliminated. For the purpose of discussion, an achievable figure of 7 percent will be used as a goal.

1.4 Regional Water System(s)/Authority(ies)

Regional water authorities are established to manage regional water resources in areas where federal, state, municipal, irrigation, institutional, and other agencies determine there is a need to plan and coordinate water-related activities on a cooperative basis. Their formation can also be mandated through state or federal direction. No regional water authorities currently exist in the planning area, although one has been studied and planned in the Española-Pojoaque area. It is difficult to quantify and characterize the effects of such agencies on water quality and quantity management; however, their formation would most likely have several region-wide effects:

- Professional and improved planning, management, operations and maintenance
- Improved metering, permitting, record keeping, and standards monitoring and enforcement
- Improved ability to prioritize and efficiently implement infrastructure enhancements, planned initiatives such a conservation programs, and equitable and effective cost reimbursement strategies
- Improved ability to draw and use internal and external funds

Such actions would obviously contribute to overall region-wide efficiency in water use in the planning area. Region-wide authorities could be established for sub-areas within the planning area or for the entire area. They could also be instituted for irrigation system water uses and/or municipal and industrial system uses. Such regional entities require vested and delegated legal authorities from the joined parties that allow them to manage their responsibilities. They also require medium time frames for establishment and development of efficient operations on the order of three to five years.

2. Technical Feasibility

All of the options described in the previous section are technically feasible, as discussed in Sections 2.1 through 2.4.

2.1 Linings and Pipes for Unlined Irrigation Channels

Irrigation conveyance systems can be broken down into three classes: main, distributory, and field canals, with each conveying a correspondingly smaller flow. *Main canals* take water for entire irrigated command areas from some source and carry it to *distributory canals,* which issue water to *field canals,* which deposit water onto agricultural fields. Each of these canal types lends itself to lining or piping of some sort. The canal lining and pipe replacement necessary to reduce water loss is well understood and practiced worldwide. Available technology includes linings made from compacted impervious earthen material, gunite, soil-cement, concrete, and plastics. Various types of pipe materials and systems are also used for the same application.

The issue is complicated by the effects of channel lining or piping, such as reduction or elimination of useful and aesthetic vegetation and trees now found growing along canal alignments that use seepage water for nourishment. Some amount of this seepage water may also be a meaningful component of shallow groundwater recharge. Lining canals also must be done thoughtfully so as to minimize the future destruction or breaking of linings by farmers who might want to install new or change the location of existing farm turn-outs, for example.

2.2 San Juan-Chama Water Regional Pipeline

Large-diameter and long (more than 50 miles) closed conduit water conveyance systems are in use today all over the world carrying raw or treated water from some source to some point of use. Complicating factors for using a closed conduit to carry San Juan-Chama project water include right-of-way acquisition, routing to avoid pump stations, compliance with the Clean Water Act, requirements of the National Environmental Policy Act (NEPA), and the need to build in possible future needed capacity for the delivery of water volumes in excess of those now allocated. Future water rights purchases, leases, and or assignments might one day augment the existing level of San Juan-Chama project water past its total current allocation.

2.3 Water Distribution System Repair and Maintenance

Three main steps are essential in repairing water distribution systems: (1) leak detection, (2) determination of the exact location of each individual leak, and (3) repair of leaks determined to be an issue. The technology exists to carry out very sophisticated and effective computer and geographic information system (GIS) assisted leak detection and location surveys in water supply systems. The technology to repair water line leaks is also available and is in use in public water systems throughout the world. Complicating factors involve the locations of some of the water lines that are now on private property, the age of some of the pipe materials and the difficulty in effectively repairing them, and the need to conduct repair operations on a recurring annual basis.

The definition of unaccounted-for water also will differ somewhat for each locality, and the inability of small systems to perform this work with in-house resources will be an issue.

2.4 Regional Water System(s)

Few technical issues are associated with forming a regional authority. However, sophisticated managerial skill is required to plan and establish an effective entity that would be poised to achieve its goals. Complicating factors include establishment of rules and regulations, procurement of required equipment and materials, staffing with experienced technicians, locating and using “as-built” facility drawings, and developing experience with systems.

Regional authorities can be a board of several members, each from a constituent entity that mandates system direction to members. Alternatively, regional authorities can be formed to manage, operate, and maintain certain member system infrastructure such as the relatively larger source withdrawal, treatment, and transmission facilities that are deeded to them. Authorities formed under the latter scenario have significantly more control of their members’ activities and are more able to accomplish the objectives for which the authority was formed.

Regional water systems are defined here as authorities that are formed by amalgamating the areas and responsibilities of numerous systems, whether they are rural systems or systems managed by a county, municipality, city, or other entity. An existing or new municipal water system is not a regionally managed system in itself.

3. Financial Feasibility

Each of the four options examined have financial feasibility issues that relate to capital costs, recurring annual costs, and the existing or possible future pricing of water that are beyond the scope of this white paper to address; however, the expected order of magnitude of costs to implement each option are discussed in Sections 3.1 through 3.4.

3.1 Linings and Pipes for Unlined Irrigation Channels

Agriculture is an economic activity. It is normal to invest funds in such projects if they can be shown to have a positive rate of economic return. Some agricultural projects, however, do depend on publicly dispersed funds, and this option might be one of those cases. Most of the irrigated acreage in the study area is not commercial-scale agriculture and does not generate cash flows sufficient to justify investments in water delivery system improvements. Consequently, funding from sources other than the owners of irrigated land is likely to be necessary.

The following example attempts to shed some light on the magnitude of savings that might be realized if some meaningful percentage of canals in the planning area were lined (assuming that they are now all unlined). Assume that unlined canals lose 36 percent of the water that they convey and that 60 percent of all lost water could be saved by lining 75 percent of all canals. If 62,000 acre-feet of water were withdrawn for irrigation in 1999, lining those canals would equate to savings of 13,392 acre-feet. Assuming that this “lost” water provides no benefit and that the sale price per acre-foot of water is $5,000, then this savings equals more than $66 million.

To estimate the cost of lining the canals (and saving the $66 million), assume that 10,333 acres of irrigated land exist in the planning area (irrigation duty = 6 acre-feet per acre) and that for each acre, 206 feet of some type and size canal is needed to deliver water to fields, for a total of more than 2.1 million feet of unlined canal. To line 75 percent of this total footage at an average lining cost of $40 per foot would cost more than $63 million.

The above cost-estimating exercise does not include the annual recurring maintenance cost or any other costs for planning and managing such a program. Additional capital costs would also be necessary to address non-channel construction required to improve irrigation delivery systems under such a program.

For the purposes of this study, therefore, lining ditches in the planning area is roughly estimated to cost between $50 and 100 million. However, there would be a significant return of saved water.

The use of pipes in irrigation systems in lieu of lined canals saves even more water as it virtually eliminates evaporation. To the extent that water that seeps into the ground through unlined canals reaches the regional groundwater system, it is not lost to evapotranspiration and is available for other uses in the planning area. When using pipes in irrigation water conveyance, however, complicating operational issues are introduced, including increased potential for system clogging, reduced infrastructure flexibility, and increased headworks infrastructure (bars, screens) and maintenance. The costs for planning, designing, and installing a piped irrigation system can be generally compared to a lining project in magnitude. The additional amount of water saved would be equal to the amount of evaporation prevented. In the planning area this amount is estimated to be an additional 670 acre-feet or approximately 5 percent of the total estimated losses from unlined canals.

3.2 San Juan-Chama Water Regional Pipeline

The cost of planning, designing, building, and then operating and maintaining a pipeline for transporting water from the San Juan-Chama Project would be large. For a rough estimate of the cost, several assumptions were made:

- A regional pipeline would only include those waters allocated to the planning area.

- A 53-mile (straight line distance from Santa Fe to Lake Heron), 48-inch-diameter pipeline could be used to transport the water.
- No pump stations would be required.
- The linear foot construction cost would be $300
- The right of way cost would be $0.20 per foot
- Planning, design, and project management costs would be 40 percent of the total cost of the job.

Based on these assumptions, the total project cost would be more than $117 million.

To calculate potential savings, assume the following:

- The planning area has 10,835 acre-feet of allocated San Juan-Chama water and it loses 10 percent, or 1,084 acre-feet, of this water in conveyance while in the Rio Chama and the Rio Grande.
- All of this water can be saved if the planning area's allocation was piped from Heron.
- Water to replace losses is purchased at $5,000 per acre-foot

Based on these assumptions, a cost savings of just over $5.1 million would be realized.

An additional cost would be the feasibility and environmental studies that would be required prior to building a regional pipeline. These studies would cost at least several million dollars. Other costs would include those related to community involvement, such as public notice of construction activities near a community, public meetings, and inter-jurisdictional coordination when construction involves federal or tribal land.

3.3 Water Distribution System Repair and Maintenance

The three largest municipal water systems in the planning area (Santa Fe, Los Alamos, and Española) serve a total estimated population of just over 89,000. Each of these systems is managed, operated, and maintained by a full-time professional staff, and each has an ongoing leak repair program to help reduce unaccounted-for water. While the amounts of unaccounted-for water in these systems (12 percent in Santa Fe [estimated], 10 percent in Los Alamos, and 14.5 percent in Española) are within industry-standard acceptable levels, they are above the 7 percent achievable goal proposed in Section 1.

The planning region also includes 76 other small public water systems that serve 50 to 1,500 people each. Experience with these systems indicates that unaccounted-for water ranges from 15 to 50 percent. To estimate costs savings possible through this option, it was assumed that the 76 smaller systems serve a combined population of just over 22,500 people and that 25 percent of the total withdrawals in these systems is unaccounted for.

Water withdrawals in 2001 from each of the three large systems are known and total 11,304 acre-feet. The other smaller 76 systems are estimated to have withdrawn 1,222 acre-feet. Current losses throughout the region can therefore be estimated at 2,397 acre-feet. Reducing unaccounted-for water through a leak detection and repair program to 7 percent would save 1,078 acre-feet or, at $5,000 per acre-foot, $5,300,000.

The basic cost of the program to carry out these leak detection and repair activities in the three major municipalities and the 76 smaller systems can be estimated at about $12,000,000 in its first year.

3.4 Regional Water System(s)

Regional authorities can effect real and significant improvements in water delivery, quality, customer service, conservation, and environmental management; however, they do so at a price. While they add technical and managerial value, they can be viewed as just an added layer of government, and adding this regional capability arguably reduces the need for those capabilities in existing member service organizations. Downsizing existing service organizations when a regional authority is established does sometimes (but not always) take place. Existing organizations, especially smaller ones, will sometimes take the opportunity to reorganize management, operations and maintenance responsibilities to be more efficient, instead of downsizing.

An effective regional authority could provide economies of scale in managing facilities and in using technology and information, and may thus be able to provide services at a lower cost than each individual entity could achieve on their own. Such additional efficiencies, however, cost additional money. The planning and establishment of a regional authority can sometimes draw external funding assistance in a similar fashion to a capital improvement project. But any annual recurring costs of the regional authority that are not offset by reductions in annual recurring cost for member organizations must be recouped by water user charges. An increase in monthly water rates to all types of users might be 10 to 40 percent of existing rates, depending on the size and type of authority formed. Such a cost increase may well lead to an increase in water withdrawal and consumption efficiency commensurate with the additional costs.

4. Legal Feasibility

There are no legal barriers to improving water delivery systems to reduce leakage and evaporation. The legal issues arise in considering how much of the “saved” water is available for use and by whom. Currently, any municipal or mutual domestic water entity that reduces leakage in its water delivery system increases its water supply correspondingly; such entities are free to use all of the “saved” water.

The situation gets complex if one considers, for example, whether a municipality could pay an acequia or irrigation district to line its canals in return for the municipality receiving some or all of the “saved” water. Such a transaction would require State Engineer approval, as it would be a change in location and purpose of use. Approval would be given only if it could be conclusively demonstrated that no net increase in water depletions would result. In other words, the State Engineer does not view stopping leakage of water from ditches into the aquifer as “saving” water because that water remains in the hydrological system one way or the other (either on the surface or underground). The only true savings, according to the State Engineer, come when evapotranspiration is reduced or waters otherwise lost to the system are retained. Moreover, since the State Engineer allows water rights owners to transfer only their consumptive irrigation right (CIR) rather than their diversion right, any increase in delivery efficiencies would not be part of the CIR and thus could not be transferred by the farmer to the city, according to the State Engineer's current interpretation of the law. Finally, a reduction in depletion at one place of use may simply increase the supply for other users along an acequia, with no net savings that can be transferred.

Any proposal to pipe San Juan-Chama water from either Heron or Abiquiu Reservoir would be a major construction project requiring compliance with the National Environmental Policy Act (42 U.S.C. Section 4321 *et seq.*), the Endangered Species Act (16 U.S.C. Section 1531 *et seq.*), the Clean Water Act (33 U.S.C. Section 1251 *et seq.*) (permit needed for the diversion from Heron or Abiquiu and for any arroyo or river crossings), and possibly other statutes, such as the National Historic Preservation Act (16 U.S.C. Section 470 *et seq.*) and any applicable local land use and environmental requirements. Removal of the water from the river system much higher in the Rio Grande/Chama watershed than would occur under other plans under consideration could make obtaining necessary approvals from the U.S. Fish & Wildlife Service under the Endangered Species Act more problematic than alternate San Juan-Chama diversion schemes, if any endangered southwestern willow flycatchers or other listed species are located between the proposed pipeline diversion and the alternate proposed place of diversion. In addition, if San Juan-Chama contractors in this region follow the Albuquerque model and propose to divert both their full amount of contracted San Juan-Chama water plus an equivalent amount of native Rio Grande water, it would be far more difficult to get State Engineer approval for such diversion from Heron or Abiquiu than if the diversion were further down the system and closer to the place where return flows rejoin the river. In general, compliance with federal, state, and local laws would be significantly more onerous for a pipeline taking the water from Heron or Abiquiu than they would be for a diversion and pipeline significantly further down the river system (such as near Otowi) because the pipeline would be far longer and thus its environmental impacts more significant, and because the water would be removed from the river system far upstream from where it would be used and where return flows would rejoin the river.

In addition, rights of way would have to be negotiated with all landowners along the route of the pipeline, which would likely include Pueblos, other governmental entities, and private landowners.

5. Effectiveness in Either Increasing the Available Supply or Reducing the Projected Demand

The four options vary in their anticipated effectiveness:

- *Linings and pipes for unlined irrigation channels:* If planned and carried out well, a project that resulted in lined canals and/or piped irrigation delivery systems in the planning area could provide more water to agriculture, thus reducing demand at the diversion structure, and/or increasing system return flows, and in turn, providing more water for downstream uses. While the conceptual costs seem high, the cost of "saved" water appears to be large in comparison to the investment. A project that focused on this activity could also be implemented over a period of time (e.g., 10 years), thereby lessening the impact of a major one-time capital outlay. As discussed in Section 3, if 60 percent of all lost water could be saved by lining 75 percent of all canals, approximately 13,000 acre-feet per year could be saved (based on 1999 irrigation withdrawals) in years with a full supply. Reappropriation of this "saved" water and transfer to domestic use is highly uncertain, but improved efficiency for the existing users could extend the supply in dryer years.

- *San Juan-Chama water regional pipeline:* While there is water to be saved by using such a facility, its conceptual cost appears to be significantly higher than the apparent value of the water that will be lost through conveyance of San Juan-Chama water in the Rio Chama and the Rio Grande. As discussed in Section 3, this option would potentially save 884 acre-feet of water per year.

- *Water distribution system repair and maintenance:* Again, while there is water to be saved by adopting and implementing such a program in the planning area, the cost of the activities to achieve some desired goal are high in comparison to the possible value of water saved. However, smaller projects in the smaller systems with large amounts of unaccounted-for water would be worthwhile.

- *Regional water system(s):* While comparisons of establishment and recurring costs to the value of water savings are difficult, this option will likely be beneficial and cost-effective. The degree of effectiveness will also increase as the size of the regional system and its associated responsibilities and authorities increase. This is likely a worthwhile first step in addressing any water issues in the planning area.

6. Environmental Implications

The environmental implications of the four options vary:

- *Linings and pipes for unlined irrigation channels:* Any such project must be planned and designed to account for groundwater recharge requirements if it is determined that such recharge does occur and is beneficial. Clean Water Act and NEPA regulations must be addressed. As there will be impacts to flora, fauna, water, and soil, any such project warrants and will be required to undergo, at a minimum, an environmental assessment. In particular, lining or piping community acequias would reduce water available for acequia-fed riparian vegetation and habitat. Nevertheless, all of the issues related to the environment can be easily addressed if these projects are properly designed.

- *San Juan-Chama water regional pipeline:* This option would entail major impacts to the river ecosystems, the flora and fauna of the river and its environs, and some endangered and threatened species, because water now in the pipeline will drastically reduce seasonal in-river flows that are required to sustain these species. These possibly huge impacts would become a major focus of public scrutiny and would most probably preclude such a project.

- *Water distribution system repair and maintenance:* No significant environmental implications are associated with this option.

- *Regional water system(s):* Establishment of a regional water authority would most probably benefit the environment due to improved water quality in rivers and streams as a result of, for instance, more efficient wastewater treatment.

7. Socioeconomic Impacts

Each of these options will have socioeconomic impacts of varying degrees that mainly relate to increased charges for water for all customers. Those who can afford such cost increases absorb them, while those who can't must consider and/or make changes in lifestyles. Threats to established rural lifestyles are perceived by many in New Mexico as a threat to their culture. The rural and less affluent population in the planning area will view increased water charges as additional pressure that makes their lives more difficult and as additional proof that those who are more affluent than they and who practice a more urban and less traditional lifestyle are negatively affecting them.

Potential opposition as a result of these viewpoints can be mitigated by implementing a cost structure other than the traditional system of charging each customer similarly for the same unit quantity of water. Other water pricing and reimbursement strategies exist that result in cost apportionment based on uses and ability to pay. Such systems might offer some relief from certain negative socioeconomic effects.

Other specific socioeconomic impacts include:

- *Linings and pipes for unlined irrigation channels:* If planned and designed properly, such a program would have little impact. Participation of irrigators from start to finish in such a project will also ameliorate any negative impacts. Some negative impacts may, however, occur. Lining or piping community acequias, in particular, could reduce groundwater recharge in areas where residents rely on shallow domestic wells. Such a program might also result in an increase in maintenance costs. Resistance to change on the part of irrigators may be an issue to overcome. Unless such a project addresses agricultural sustainability issues, no increase in agricultural income would be expected from such a project. However, some irrigators at the ends of some irrigation canals will probably receive more water and therefore will economically benefit from the program.

- *San Juan-Chama water regional pipeline:* The socioeconomic impacts of this option are difficult to predict. During construction, there would be a great deal of disruption in areas where large-scale heavy construction activities occur.

- *Water distribution system repair and maintenance:* No socioeconomic impacts are associated with this option except for higher customer water rates due to the cost of carrying out these activities on annual basis.

- *Regional water system(s):* This option has few real socioeconomic impacts. Customer water rates would be higher due to increased overall system recurring annual management and O&M costs. In addition, there would be major hurdles to overcome in terms of trust between potential member entities, and voluntary regional authority formation is often difficult.

8. Actions Needed to Implement/Ease of Implementation

The ease of implementation and actions needed to do so are as follows:

- *Linings and pipes for unlined irrigation channels:* Considering the cost of this initiative, an existing and or new external funding program would need to be established that would be devoted to assisting farmers and acequia organizations in this endeavor. An alternative to developing and providing an external funding program might involve legislating the activity through a requirement that farmers reduce seepage and evapotranspiration from their canals by some percentage. Tax breaks and subsidies could also be legislated for farmers who comply with such legislation. A program to carry out such activities can be designed, can work, and can be fairly easy to implement. Major involvement of irrigators in planning, design, and construction is required to ensure project viability over a useful facility design life. Such programs have been successfully carried out on small irrigation systems throughout Africa and Asia for the last 40 years.

- *San Juan-Chama water regional pipeline:* This option would require extensive feasibility studies as well as environmental impact assessments, particularly with regard to threatened and endangered species. In addition, the high cost of this option would require considerable financing and/or funding from outside sources.

- *Water distribution system repair and maintenance:* Implementation of a planning-area-wide program to carry out this goal would have to be the result of an agreed upon objective by all 79 water system governmental entities. Then all 79 entities would either need to obtain external funding to pay for this program or raise user charges to do so, and the external funding or user charge increases would have to be sustained over time, as this is an annual program with ongoing costs. This option would be easy to implement although it would result in temporary construction activities on private property in some cases where water lines run in public easements on private land.

- *Regional water system(s):* The formation of regional authorities to administer and manage water resources is a political decision. Community-wide trust and understanding of the logic of and need for regional authorities can sometimes drive the needed agreement by neighboring entities. In other cases, the formation of such authorities is the result of a court or federally ordered action. In either case, major detailed cost and technical studies are required to justify and demonstrate the efficacy of such decisions.

9. Summary of Advantages and Disadvantages

The advantages and disadvantages of each of the four options are outlined in Table 1 and summarized below:

Table 1. Advantages and Disadvantages of Water Conveyance Options

Water Conveyance Option	Advantages	Disadvantages
Linings and pipes for unlined irrigation channels	• Increased available supplies • Value of water saved high • Improved irrigation coverage • Increased return flows • Minimum environmental issues • Minimum cultural impact • More crops, more farmer income • Legally feasible	• Must be done right • Cost high • External funding probably required • Additional studies required • Decreases aquifer recharge • Impacts riparian vegetation • Accurate assumptions difficult due to water supply fluctuations
San-Juan Chama water regional pipeline	• Increased available supplies • Minimum cultural impact	• Difficult to design, build • Cost high • Value of water saved low • Major negative environmental impacts • Major right-of-way issues • Legal hurdles • Politically difficult
Water distribution system repair and maintenance	• Increased available supplies • Cost-effective for small systems • Minimum environmental issues	• Not cost-effective for major cities • Cost high • Value of water saved low • High annual pass-on cost to customers • Additional costs to low income families
Regional water system(s)	• Increased available supplies • Reduced projected demand • Medium costs • Value of water saved high • Better financial management • More external funding available • Improved water quality • Positive environmental impacts • Improved water systems efficiencies • Water conservation programs	• Politically difficult • Pass-on costs to customers • Additional costs to low income families • Scarcity of qualified staff

- *Linings and pipes for unlined irrigation channels:* This option is expensive, but significantly increases supply for the water users, particularly during drought periods. Implementation will not be easy but is feasible.

- *San Juan-Chama water regional pipeline:* This option comes with too many environmental issues to overcome and too high a cost for the small potential return in value.

- *Water distribution system repair and maintenance:* A region-wide program may not make sense in the Jemez y Sangre planning region, but small systems that experience high unaccounted-for water levels should address this issue.

- *Regional water system(s):* This option is politically difficult if not impossible, but could ensure that long-term water delivery efficiencies and improvements occur. Quantification of the benefits of any potential regionalization requires a cost-benefit analysis.

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